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Technical Lesson 59-A

AVIATION RADIO EQUIPMENT FOR TWO-WAY COMMUNICATION

Two-way communication in aviation requires that the equipment and controls be so arranged as to provide a quick and simple means for carrying on direct radio telephone conversation between planes in flight and ground stations. The complete equipment is divided into two independent sets of units or parts, one set for installation in the plane where space is at a premium and the other set for installation at the ground station.

The photographs, the schematic diagrams, and the data for this lesson on modern radio equipment used in aviation are given through the courtesy of the Western Electric Company from their bulletin, "Aviation Communication Equipment". The two-way communication equipment described in this lesson is designed for short-wave work, the transmitter used in the airplane being known as model 8-A and the receiver model 9-B. These sets use Western Electric tubes throughout.

The equipment which is installed in the airplane consists principally of a short-wave radio transmitter and a short-wave radio receiver, together with the sources of power for each of these units. In addition to these main units there are the necessary microphones, headsets, and remote volume, tuning and switching control apparatus. The switching arrangement for the two-way system is made to control the long-wave radio receiver. The long-wave receiver which picks up radio range/beacon signals and weather forecast information may be bridged to use the same antenna as the short-wave receiver.

SHORT WAVE RADIO TRANSMITTER FOR THE AIRPLANE. An examination of the schematic circuit of the radio transmitter and microphone in Figure 1 shows that it consists essentially of a temperature controlled quartz crystal oscillator, a frequency doubler, a modulating power amplifier, and antenna tuning unit. Also there is the speech input circuit to which the microphone is connected and several audio-frequency amplifiers which are used to step up the voice currents received from the microphone to a suitable level before they are introduced into the modulating amplifier circuit to act on the high-frequency oscillations present in the circuit. This high frequency is the carrier frequency that is radiated from the antenna through space. The operating frequency is maintained within certain prescribed limits as required by the Federal Radio Commission this being possible under all conditions by the use of the quartz crystal oscillator.

A total of two 5 watt and four 50 watt vacuum tubes is used in the radio transmitter which gives at complete modulation, a peak power output of 200 watts. A high percentage of modulation means that the voices are heard distinctly, or we say the articulation is good, and this is brought about by the action of the voice frequencies on the high-frequency oscillations which causes them to vary in amplitude between great limits. With poor reception errors can easily occur.

A general discussion of the relationship of the various circuits in an aircraft transmitter will show how many of the radio principles which you have already studied are applied in practice, such as vacuum tube oscillating circuits, how power is obtained for energizing the vacuum tubes and so on. In the following paragraphs we will explain the purpose of these circuits and also the special features which are peculiar to aviation equipment.

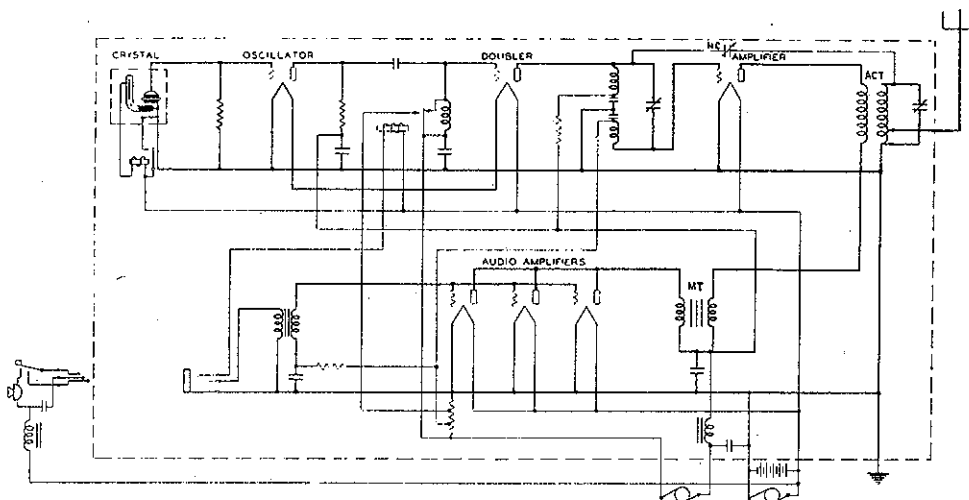


Figure 1

Let us first consider the crystal oscillator. This unit is assembled in an isolantite holder provided with three prongs in the base for connection to the ground, heater, and thermometer contacts and is designed to plug into a socket similar to one which is ordinarily used to hold a vacuum tube. There is a terminal on the top for connection to the grid of the oscillator tube.

The quartz crystal oscillator is clamped firmly between two metal electrodes, one of which is held at a temperature of 55 degrees centigrade by an imbedded electrical heater. The heater is controlled automatically by a thermostat of the mercury-column, contact-making type. The temperature control device consists of a cylindrical metal shell, a resistance unit and the contact-making thermometer, and the whole unit operates to control the heat as follows: The thermometer contacts which are short-circuited by the mercury-column at the operating temperature operate a relay which in turn controls the amount of current passing through the wire of the heater element. One end of the shell forms one contact surface for the crystal as is clearly shown in the diagram in Figure 1.

This crystal is used to control the frequency of the oscillations which are generated when the crystal is connected to a vacuum tube, that is, to the 5 watt oscillator in the circuit diagram. The crystal is very carefully ground to give it the proper thickness so that the oscillations generated by it will have a carrier frequency which is one-half of the frequency used to radiate for communication purposes. Our students should understand that a vacuum tube circuit can be adjusted to produce several strong harmonics along with its fundamental, and that one of the harmonics will be selected by an associated oscillatory circuit when the latter is made resonant to that particular harmonic frequency.

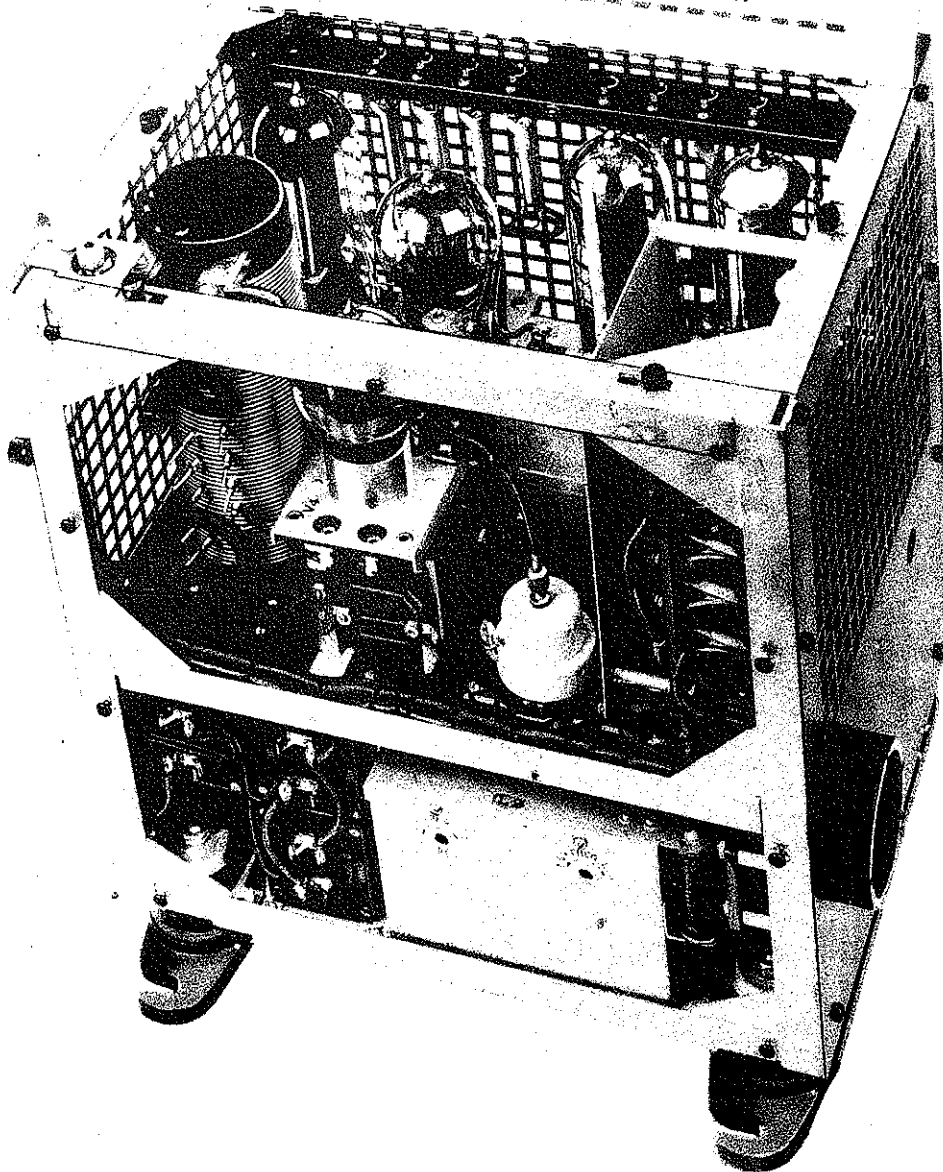


Figure 2

Figure 2 is a photograph of the interior of the airplane transmitter under discussion; this view clearly illustrates the position of the crystal holder and the grid connection to the grid of one of the 5 watt tubes.

To continue our explanation, a 1050 volt circuit leading from the generator end of the dynamotor, shown in the lower part of the diagram, furnishes the d-c plate voltage required for the 5 watt oscillator tube, but since this voltage is much higher than that required for a 5 watt tube it must be lowered and this is accomplished by causing the plate current to flow through a series resistance. The drop in voltage obtained across this plate resistor equals the value of its resistance in ohms multiplied by the amount of plate

current in amperes passing through it. Also, you will notice a condenser inserted between the low side of this resistor and one side of the filament, which if you trace out the circuit shows that the series resistance and condenser together form a radio-frequency circuit from plate to ground. In the grid circuit of the next tube marked "doubler", there is a tapped coil which provides the necessary plate inductive reactance for the tube and its associated circuits to oscillate. The oscillator is controlled for simplex operation of the transmitter by a relay which short-circuits the grid coil just mentioned when the transmitter is not in use, this being the position the relay occupies in the diagram.

In this transmitter the plate of the oscillator is coupled to the grid of the second 5 watt tube or "doubler" by means of a condenser called a "stopping" condenser. The grid circuit of the "doubler" is untuned and the r-f energy is transferred from the plate of the oscillator through the stopping condenser, the latter being used to prevent the d-c plate voltage of the first tube from being applied directly to the grid of the second tube. This tube in the frequency doubler circuit is given a high negative grid bias provided by a grid leak resistance in addition to the usual bias voltage which is obtained by connecting the grid return to one end of a tapped resistor shown in the lower center part of the diagram, the other end of the resistor being connected to the filament. In addition to the doubler circuit fulfilling the function of providing a desired harmonic which becomes the "carrier," it also amplifies this high-frequency energy to a certain extent as determined by the normal amplifying properties which are common to the action of every vacuum tube. By this we mean that for a given amount of operating voltage applied to the grid there is always produced in the plate circuit a current which fluctuates in greater proportion than the grid voltage which caused the action.

The plate circuit of the second tube is tuned to the double frequency and is coupled by a split coil to the grid of the modulating amplifier which is the third tube. Positive plate voltage for the second tube is obtained from the high voltage d-c dynamotor through a series resistor, as indicated in the diagram, in order to drop the voltage to the required value.

Now that we have the required transmitting frequency provided by the doubler circuit, then it is only necessary to step up the power of the oscillations to increase the transmitting range and to cause them to be modulated according to the voice currents resulting from the sound waves which strike the microphone diaphragm when it is spoken into. Both of these functions are performed by the third or final tube in the radio-frequency portion of the transmitter. This is known as the modulating power amplifier.

The output of the doubler tube excites the grid circuit of the final radio-frequency amplifier, which is a 50 watt tube, and it delivers a carrier power of 50 watts to the antenna circuit through an antenna coupling transformer marked ACT in the diagram in Figure 1. This final stage of amplification is neutralized to prevent self-oscillation in this circuit, the neutralizing adjustment being made by a variable condenser marked NC.

The plate supply to this final stage is modulated by the introduction into its plate circuit of the speech frequency output of three 50 watt vacuum tubes connected in parallel. This series of tubes comprises the audio-frequency portion of the transmitter. The grids of the three audio amplifiers are fed from the output of the airplane microphone through an input transformer, and the transfer

of the audio-frequency power from these amplifiers to the plate circuit of the radio-frequency amplifier is through the transformer MT previously mentioned.

Because of the small space available for radio equipment and the necessity for keeping the carrying weight of the plane down to a minimum, this entire transmitter has been very compactly designed as the photograph indicates. Its dimensions are approximately 17" high, 16" wide, and 12" deep, while its weight including tubes is only a little more than 32 lbs.

HOW POWER SUPPLY IS OBTAINED. Two of the most difficult problems encountered in aircraft radio equipment are the source of power and the antenna system for the transmitter. We will first discuss the source of power. There are three methods that can be used to obtain the requisite voltages for the tubes in the transmitter and receiver. These methods are: (a) An engine-driven generator, (b) a wind-driven generator, and (c) a dynamotor used in conjunction with a storage battery. Airplanes operated by the various air transport systems carry passengers, mail, and express and, therefore, if the operation of a plane is to be financially profitable consideration must be given to the "pay load", hence, all loads which do not produce a revenue must be necessarily limited. Aside from the fact that the radio equipment must be light in weight and compactly built there is the problem of voltage regulation which must be considered in the case of power supply when either a wind-driven generator or an engine-driven generator is used.

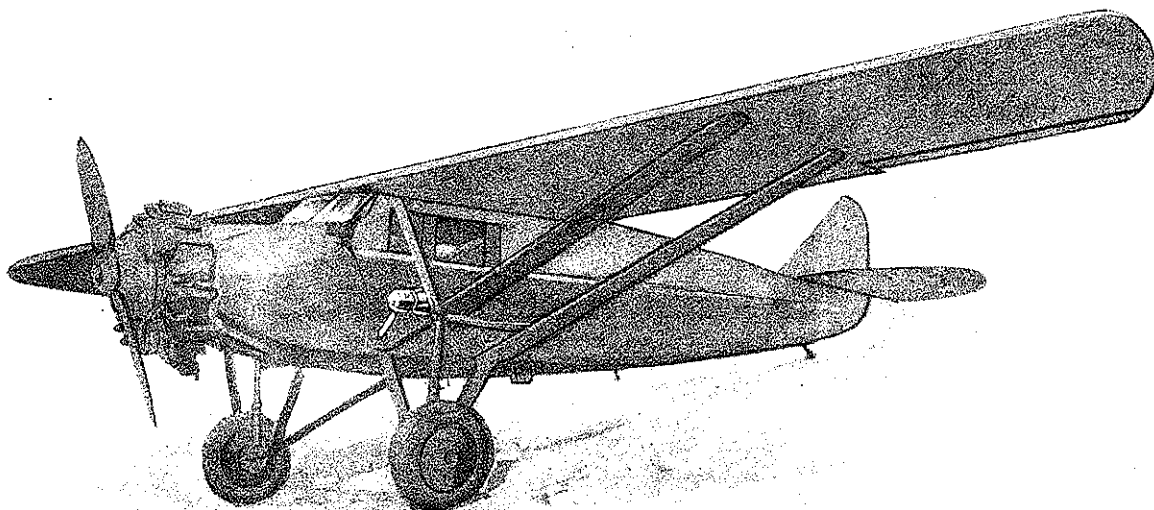


Figure 3

In the photograph in Figure 3 you see a wind-driven generator fastened to the struts of a plane. The generator is equipped with a single blade self-regulating propeller.

A brief outline of the main considerations applying to each method for obtaining radio power is given in the following paragraphs.

- (A) When an engine-driven generator is employed the plate supply for the transmitter is obtained from a generator geared to the airplane engine. Special control must be provided to maintain constant voltage automatically at all engine speeds.

For a transmitter of the type described in this lesson, 1050 volts would be taken from the plate supply, while the regular airplane battery floated across the low potential supply would furnish about 12 or 14 volts which would be used for heating the cathodes and the filaments of the tubes, and to supply current to the heater element of the thermostat control.

- (B) In the case of a wind-driven generator both the high and low voltages, or the plate and filament voltages, are supplied by the generator, and it is therefore called a double-voltage generator. Since it must be installed outside the plane it is housed in a streamlined case. The generator is driven by the action of the wind on a small, constant speed propeller, the latter being self-regulating with a starting torque such that any airplane speed in excess of seventy miles an hour is sufficient to cause the generator to come up to speed and deliver its rated output voltages. A double-voltage generator has two commutators and if used for this particular airplane set the generator would be designed for a low-voltage output of 20 amperes at 12 volts, and a high-voltage output of 0.4 amperes (400 milliamperes) at 1050 volts. One type of wind-driven generator is shown in Figure 4A.
- (C) With the third method a light-weight dynamotor is used for the plate supply. The dynamotor is operated from a twelve volt battery, which directly supplies the filaments of the tubes. A 12-15 volt, 50 ampere generator connected to the engine of the plane is necessary in order to keep the battery charged. Figure 4B shows a typical dynamotor.

In this transmitter the dynamotor method is utilized and a power plug for the transmitter is provided with three pins. Two of these are guide pins and the third is a locking pin. The locking pin is located diametrically opposite the two guide pins. After the plug is inserted in the socket, a turn of the knurled ring on the outside of the plug locks the plug securely. While anyone of the above methods may be used, the one in (C) appears the most practical since with a battery and dynamotor routine testing would be simplified and, furthermore, a pilot would be able to transmit from a forced landing. This type of power supply would include two small dynamotors, one for low-voltage plate supply for receiving tubes, and one for high-voltage plate supply for transmitting tubes. A 12 volt airplane battery operates the dynamotors and, also, supplies the filaments. Each dynamotor has two commutators and two sets of windings on its armature, one for the generator and the other for the motor.

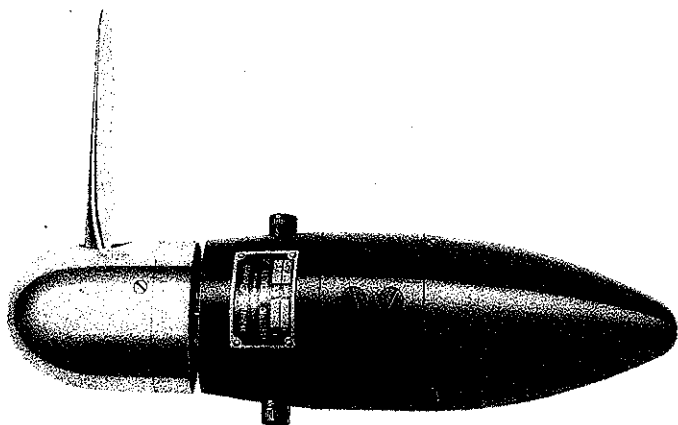


Figure 4A

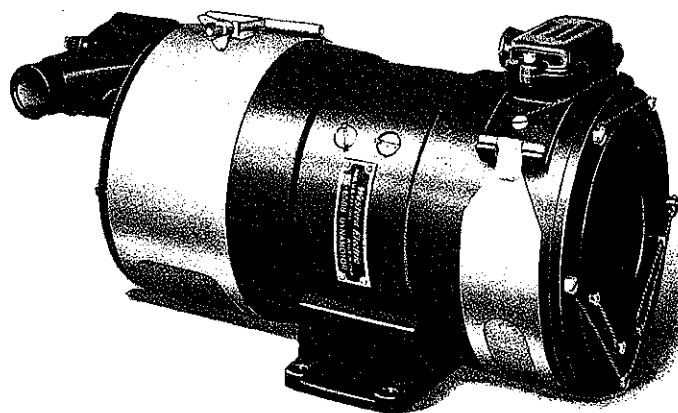


Figure 4B

In order to eliminate the commutator ripple of a generator, which is caused by sparking at the brushes, a filter system must be used. This consists of a high-voltage condenser connected in parallel to the high-tension d-c winding of the generator and a choke coil, the latter being inserted, however, directly in series with the + B line which is the positive lead feeding the plates of the tubes. If the ripple is not filtered properly it becomes not only a source of annoyance due to the continual humming sound heard in the phones, but it may set up so much noise that the voices might be "drowned out", or made inaudible, and in this event the telephone reception would be poor and unsatisfactory. Just how the choke and condenser are connected in the circuit is also shown in Figure 1.

Reference to the transmitter diagram in Figure 1 shows that the filaments of the two 5 watt tubes, marked "oscillator" and "doubler," are in series which permits them to be connected across the battery supply, while all the other filaments, or those in the 50 watt tubes are in parallel. At a voltage of between 10-14 volts the battery supplies a total filament current of approximately 15 amperes to the transmitting tubes.

THE ANTENNA FOR THE AIRPLANE. Now, having discussed the different sources of power possible for an aircraft radio set, we will explain the operation of the trailing type of antenna, since this is the type which gives the greatest range for transmission purposes. Many planes use a fixed antenna which may be erected either in a vertical or horizontal position between the wing tips, or in some other manner and, while this type has proven good for reception, yet it considerably limits the transmission range. The radio transmitter described in this lesson operates most efficiently with a trailing wire antenna, and this requires the installation of an antenna reel and guide in the pilot's cabin of the airplane. An insulated reel like the one shown in Figure 5 has been developed for use in paying out and drawing in the trailing wire antenna. The reel may be installed at any place in the fuselage convenient for the pilot or operator. It is equipped with a centrifugal brake to maintain uniform speed in paying out the antenna, and also a friction brake which holds the antenna to any given length, and a dial which gives approximate readings in meters indicating the length of the antenna wire out at any time. The antenna runs from the reel, through an insulated tube, shown in Figure 6, to the fairlead or guide which projects above and below the floor of the fuselage. There

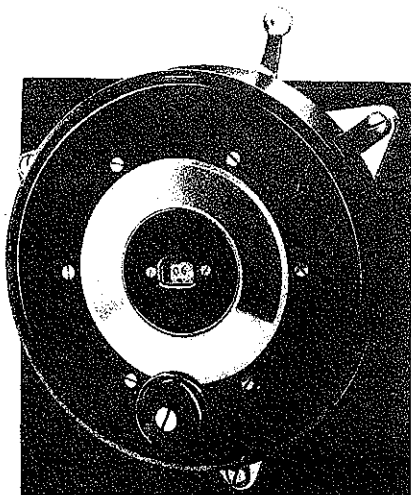


Figure 5

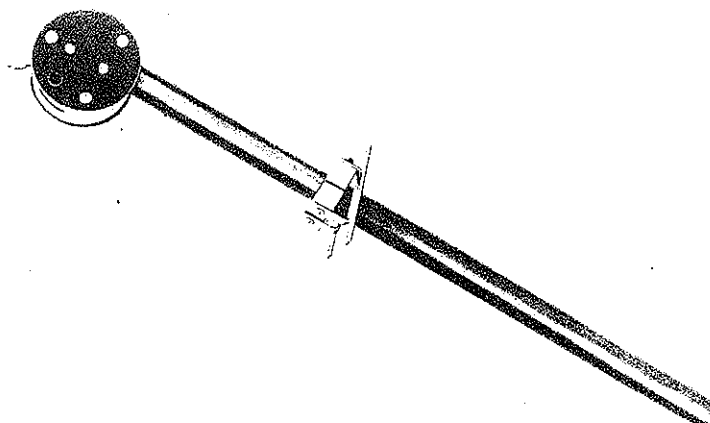


Figure 6

is a chamber at the top of the guide containing a steep pitched pulley wheel which grips the antenna tightly, thus insuring a good contact at all times. An insulated antenna lead from the transmitter passes through an opening in the side of the chamber and makes positive brush contact with the axle of the pulley wheel over which the antenna passes. At the lower part of the photograph in Figure 5 you can see the knob on the crank which is used to reel in the wire when a landing is to be made, while at the top is shown the brake lever.

There is always a compromise between using an antenna of the fixed type with its limited range of radio communication and an antenna of the trailing type due to the fact that in one case the antenna is always in a fixed position and, therefore, requires no attention on the part of the pilot or operator, whereas, in the other case, it does require a certain amount of attention. However, regardless of what type of antenna is used for aircraft, special care must be exercised to prevent the wire from becoming detached or breaking off in flight which might possibly result in its becoming entangled with the control cables of the plane. It is quite obvious that if the control cables ever become fouled from this cause it might result in a serious catastrophe.

If it is desired to use a fixed vertical antenna in preference to the trailing wire, this may be accomplished by using a tuning unit designed to couple the transmitter into the antenna. By referring to the phantom view of a complete two-way aircraft communication system, further on in this lesson, you can grasp the idea of how a vertical antenna, also called pole antenna, or strut antenna, is mounted permanently midway between the fuselage and tail.

SHORT-WAVE RADIO RECEIVER FOR THE PLANE. The radio receiver has in all six tubes which are of the Western Electric type. The first three tubes and their associated circuits constitute a radio-frequency amplifier, and the fourth tube is a space charge detector tube. These tubes are of the four-electrode variety or screen grid type 245-A. Following the detector we have the fifth tube which is a three-electrode tube type 244-A, which functions as an audio-frequency amplifier. Another tube, a 6-A ballast lamp, is used to keep the filament current constant regardless of normal supply voltage variations. The receiver cathodes and filaments are heated by the plane's 12 volt battery, while the plate voltage is taken from the d-c output of the dynamotor. Notice in the schematic diagram of the aircraft receiver in Figure 7 how the filaments of all the tubes are connected in a series arrangement so that each filament will receive its proper terminal voltage when the entire series is placed across the 12 volt battery. The plate potential supplied to this set is 200 to 220 volts.

The diagram shows that there are three tuned radio-frequency circuits; these are adjusted simultaneously to any desired frequency, within certain limits, by a gang construction of the rotor plates of the variable condensers, and they are operated from a remote tuning control unit. The variable condensers are connected across the secondaries of the r-f transformers, or tuning coil assemblies, which are made to plug into sockets similar to those provided for vacuum tubes. In this receiver there are three sets of r-f coils available to cover a frequency band of from 1500 to 6000 kilocycles, or from 200 to 50 meters.

An antenna circuit of the untuned or fixed type is employed and it is designed to give some voltage step-up of the signal energy picked up by the antenna and also to reduce the effect of this receiver upon the long-wave receiver when bridged to use the same antenna. Additional selectivity is provided to

eliminate interference from high-powered broadcasting stations which are for most of the time "on the air" transmitting at frequencies outside the aircraft band.

It is to be understood that the long-wave receiver just mentioned is the one used by the pilot to receive the radio range beacon signals and weather forecast which assist him in flying along one of the civil airways, while the short wave receiver which is now under discussion in this lesson is used only to pick up messages sent out by the ground stations of the transport air companies who operate commercial planes.

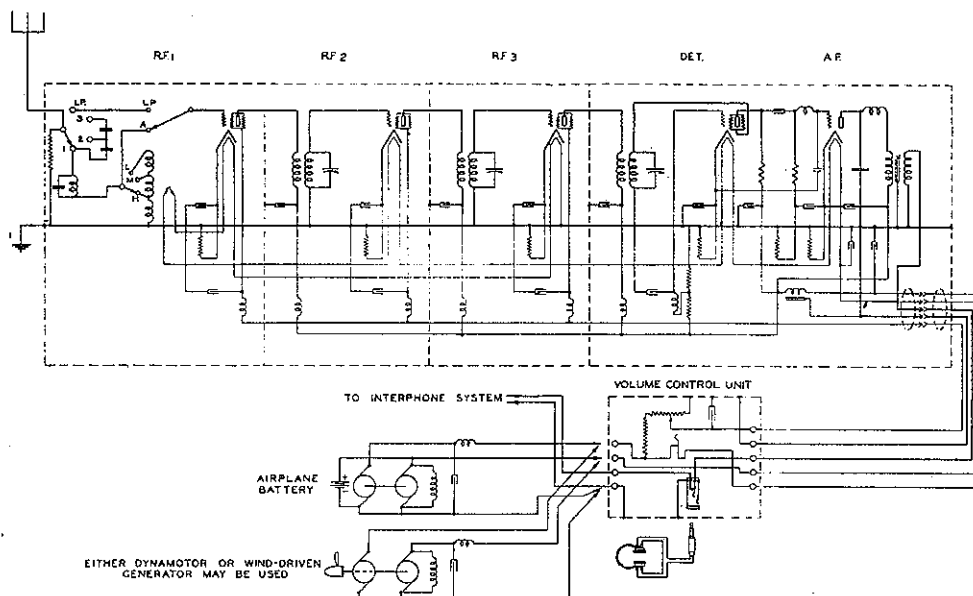


Figure 7

Again refer to the receiver diagram above and note how a switch and taps marked L, M, and H (low, medium, and high) are provided in the input circuit to the first tube in order to adjust this circuit according to the particular r-f coil used, and its coverage of a certain frequency band. This circuit functions similarly to other input circuits insofar as the oscillating signal current sets up a fluctuating voltage which is impressed between the control grid and cathode of the first tube.

Adequate shielding of the circuit elements and the tuning coils is provided by mounting the parts in individual copper shielded containers or cans, the shielding being represented in the diagram by dashed or broken lines. Thorough shielding of the parts is necessary because of the use of screen grid tubes. The whole receiver assembly is covered with an easily removable aluminum case as shown in the illustration in Figure 8, and in this photograph you can also see how the remote tuning control is attached to a length of tubing through which runs a flexible shaft.

The high sensitivity of a receiver of this kind is made possible by the wonderful amplifying properties of the screen grid tubes used in the r-f stages. These permit extremely weak signals which may be picked up by the antenna to be boosted sufficiently to give a satisfactory volume of sound in the headphones down to what is known as normal static level. It is to be understood, of course, that how well voice signals are heard in an airplane by a pilot or observer depends

upon the magnitude of all extraneous noises originating from within or without the receiver itself; these include noises set up by static, ignition, motor, propeller, and so on. A receiver of this kind is built so compact and light in construction that it weighs only about 16 lbs.

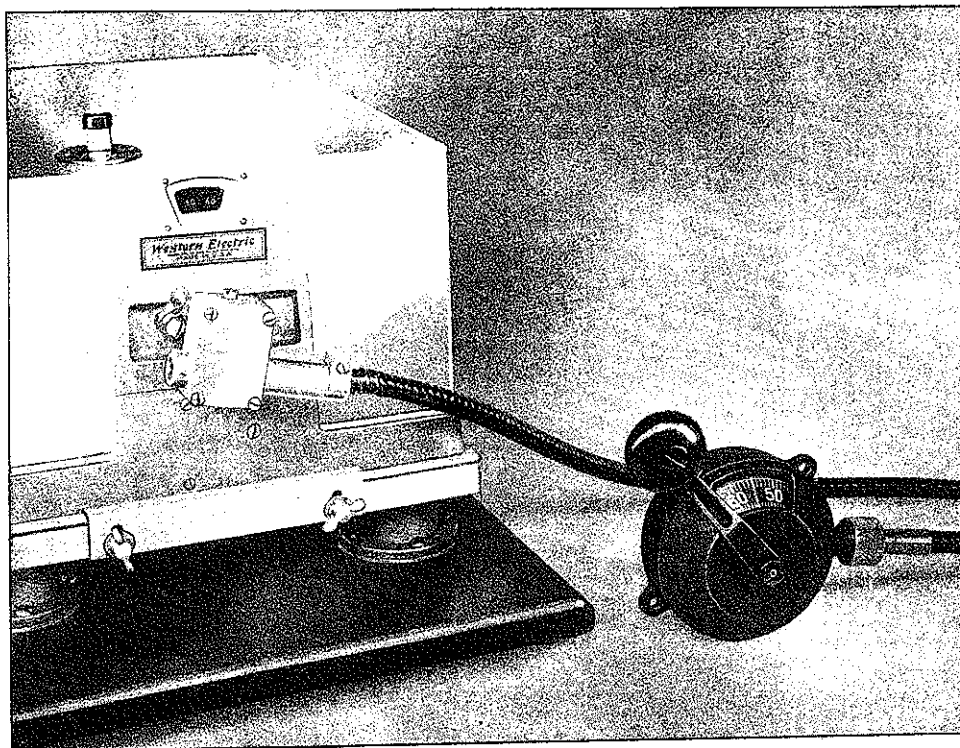


Figure 8

Before ending our explanation of the aircraft receiver, let us explain what is meant by a space charge detector tube. When a screen grid tube is used as a space charge grid tube its usual connections to the grids are reversed. A glance at the diagram shows that the normal screening grid — the one next to the plate — is used in the detector as the control grid or the one to which the signal voltages are applied, and the other grid — the one closest to the filament — is supplied with a positive voltage. With this change of connection the tube would not function well as an r-f amplifier since the screening effect is lost and potential variations in the plate circuit could then effect the grid. The advantage of this connection for a detector is to give it a lower plate resistance which results in a large amplification factor.

When a tube is to be used as an amplifier it is operated on some part of the flat portion of its characteristic curve, or plate current — plate voltage curve, but when it is to be used as a detector it is worked at some place on the curved portion which we call the knee or bend.

A few words explaining what the expression "space charge" means will now be given. Going back to your study of the action taking place within a vacuum tube you will recall that during normal operation when the filament is heated and the plate is furnished with a positive voltage that many of the electrons are attracted by the plate because of its positive potential. Any electrons which strike the plate pass entirely through the plate circuit and constitute a current flow or the tube's plate current; also, there are a few electrons

which never get very far from the filament in the first place, and some of these are pulled back by the filament because it naturally attracts electrons since it is the source of the supply; then again, there are a great number of electrons which fill up the space in the tube between filament and plate very much like a cloud or fog and it is these electrons that constitute the "space charge." Thus, it is easy to understand that the control grid of this detector tube occupies a position in a cloud of electrons, and therefore these electrons which reach the plate and constitute the plate current must of necessity first encounter this cloud of electrons or space charge. For simplifying the foregoing explanation we referred to the filament as the source of electrons and while this would be true for an ordinary vacuum tube, the student should remember that the filament of the screen grid tube in this set is used merely to heat a metallic sheath in the form of a cylinder which is the cathode. Therefore, strictly speaking, the cathode emits the electrons and not the filament. This, however, does not effect our space charge explanation.

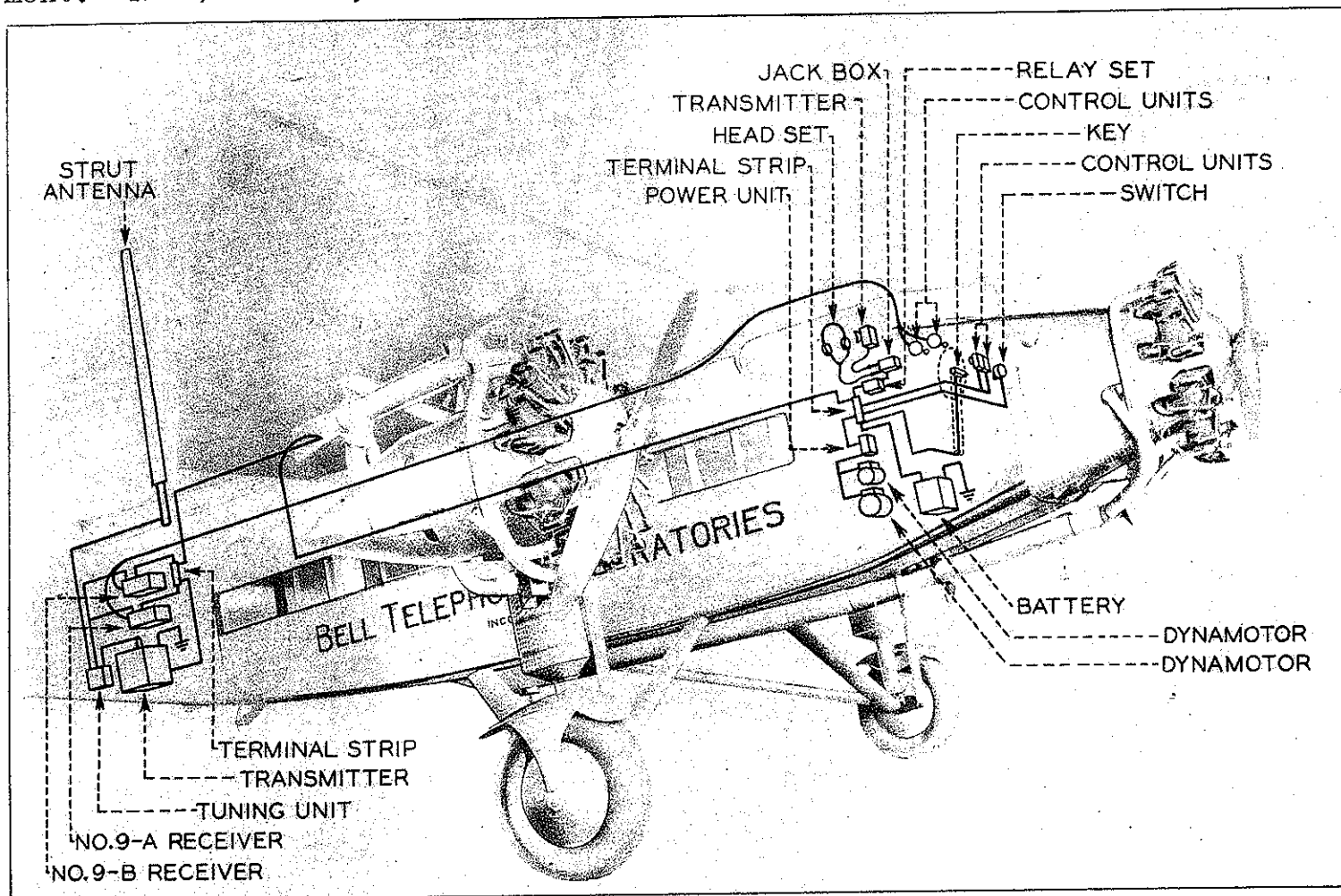


Figure 9

REMOTE CONTROL. The question arises in aircraft installation of the disposal of the separate units which make it necessary to locate the transmitting and receiving sets wherever possible in the plane. However, the radio controls must be designed in a convenient form for mounting within easy reach of the pilot in a one-man plane, or near the co-pilot in the larger transport planes which carry a pilot and a co-pilot. In the latter case the pilot is usually

Very busy watching the various instruments to maneuver the plane, especially in foggy and stormy weather when the radio offers its greatest aid. A good idea of a typical aircraft installation for two-way communication is presented by the illustration in Figure 9. Some of the components of the transmitter and receiver are mounted in the rear while all the controls are placed in the pilot's cabin and close by are the dynamotors and storage battery. All units must be carefully cushioned to protect them from plane vibrations in flight or from shocks when making a heavy landing.

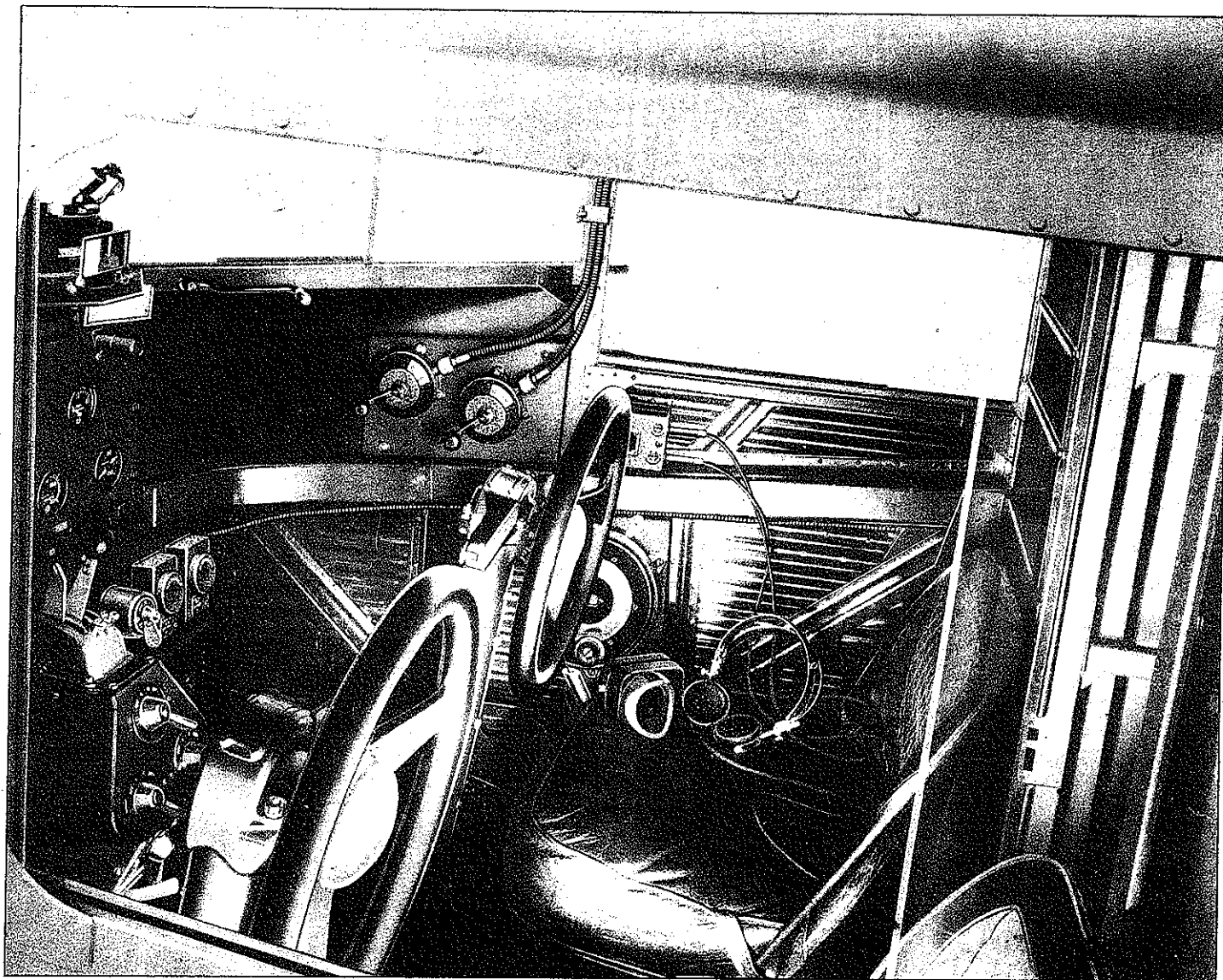


Figure 10

The photograph in Figure 10 is one looking into the cockpit of a large transport plane. A careful comparison should be made between the control units placed in the cockpit in Figure 9 which are clearly identified and the actual parts themselves appearing in the photograph in Figure 10. It can be seen that the co-pilot will have charge of the tuning controls and antenna reel. The reel is shown directly in back of the right-hand wheel. Above the reel is a jack

box into which are plugged the microphone and telephone headset; the latter two instruments are shown resting on the seat. At the upper left of the wheel are the two remote tuning controls for the tuning of the long-wave and short-wave receivers, and at the extreme left below the instrument board are the main control switch and the two remote volume control units, one for each receiver. The following paragraphs explain about these controls in more detail.

Each remote tuning control unit is equipped with a luminous dial and gears operate the flexible shaft at a speed 264 times that of the condenser shaft; this is to reduce the lost motion in this drive to a negligible amount.

The volume of reception, or gain in signal, is controlled by a volume control unit which is a tapered potentiometer as shown in Figure 7; all of the screen grids connect to its movable arm thus permitting changes to be made in screen grid voltage over a given range, and this in turn governs signal amplification.

The main switch of the radio equipment is called a master control switch and is used to turn the power supply on and off to the long-wave and short-wave receivers and transmitter when dynamotors are employed for power supply. This switch functions as follows: In the first position, marked "OFF", obviously the circuits are inactive. In the second position, marked "R", which is normal in flight, the storage battery is connected to the receiving tube filaments and, besides, the dynamotor used to supply plate voltage to these tubes and the heater circuit of the quartz-crystal chamber of the radio transmitter are energized. The dynamotor for this receiver operates on an input of 3 to 3.8 amperes at 12 volts with an output of .05 amp. (50 milliamperes) at 200 to 220 volts. In the third position, "T-R", the action in the second position is repeated; also, all power circuits are then ready for sending or receiving since the filaments of the radio transmitter tubes are energized and the dynamotor furnishing the plate supply to the transmitter tubes is started.

When the pilot is ready to transmit it is only necessary for him to start oscillations in the radio transmitter by merely pressing a push button or key located in some convenient position; the button actuates relays which perform all necessary switching functions. With the key open there is no radiation from the transmitter. Thus, during a conversation between a pilot and the operator in the ground station the push button is pressed while talking and released while listening. This "talk" and "listen" button is made in three types, one for mounting on the end of the "stick," another for mounting on a flat surface, and still another which is incorporated with the microphone; the last type is the one illustrated in Figure 10.

A complete telephone set consists of a microphone, telephone receivers, cord and plug. Sets of this kind are made up for use with a helmet to be worn by the pilots of one-man planes. To enable the pilot to use both hands in the operation of the plane the microphone is mounted on a swivel, and when not in use it can be swung over the pilot's head or under his chin. When there are a pilot and co-pilot, either one of two headsets may be used with the "silencer" type telephone transmitter or microphone. It is possible to shut out a considerable amount of interference set up especially by noisy airplane motors by careful design of the flying helmet. This will insure that the pilot's speech will be understood when reproduced by the ground station receiver and that the pilot will hear the messages sent to him. One type of microphone like the one in the photograph in Figure 10 is equipped with a soft rubber mouthpiece which is held tightly to the lips, and the microphone itself is especially made so

that its diaphragm will readily respond or vibrate when voice air waves strike it directly, but outside propeller noises will have practically no effect on it. Also, in this photograph you see telephone receivers which are of the watchcase type with a headband, but it should be mentioned that a special headset is made for aviation purposes. The latter headset consists of small moulded earpieces known as phonettes, weighing less than an ounce and which fit snugly into the ears.

RADIO TRANSMITTER FOR THE GROUND STATION. To carry on two-way communication the ground station is equipped essentially with a radio transmitter, a radio receiver, power supply equipment, microphone and telephone headset, and the usual provisions for regulating volume, and switches for controlling the power supplied to the various circuits. An examination of the schematic circuit of the transmitter and rectifier in Figure 11 shows that with the exception of a power amplifier the circuits of the transmitter proper are in many respects similar to those in the aircraft transmitter which have already been described.

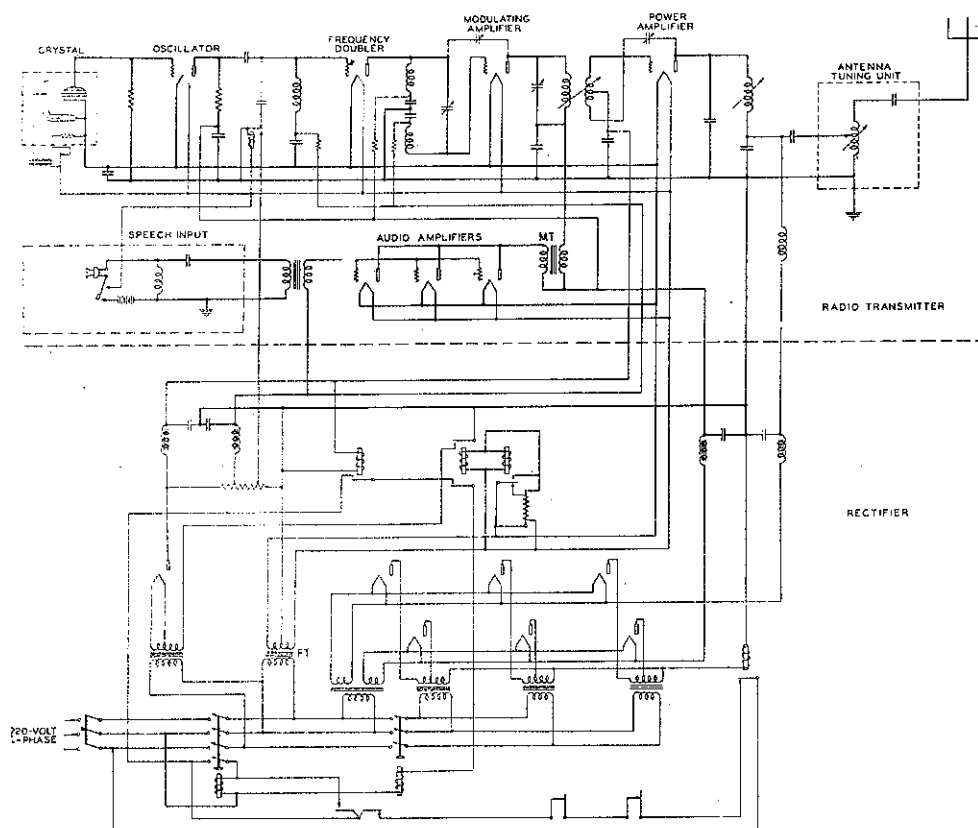


Figure 11

Of course, in the ground transmitter a power amplifier increases the transmitting range. And, in addition, a rectifier and a suitable filter system are required in order to rectify the alternating current supplied from outside mains and to smooth the rectified a-c into a practically non-fluctuating direct current for energizing the plates of the tubes. In this transmitter the filaments are supplied with a-c of the proper voltage from a step-down transformer, marked FT. The following is an explanation of the special features involved in the ground transmitter.

An interior view of the ground transmitter is illustrated in Figure 12. This transmitter consists essentially of a temperature controlled quartz crystal oscillator, a frequency doubler, a modulating amplifier, and audio-frequency amplifier, and a power amplifier; the power amplifier having been added to increase the output power supply to the antenna. The vacuum tubes used in this transmitter are all of the Western Electric type. The oscillator uses a 5 watt vacuum tube, controlled in the grid circuit by a quartz crystal similar to that used in the airplane transmitter. The quartz crystal is operated at half the desired frequency and a second 5 watt vacuum tube with a high negative grid bias is used to produce harmonics, the second harmonic being selected in the plate

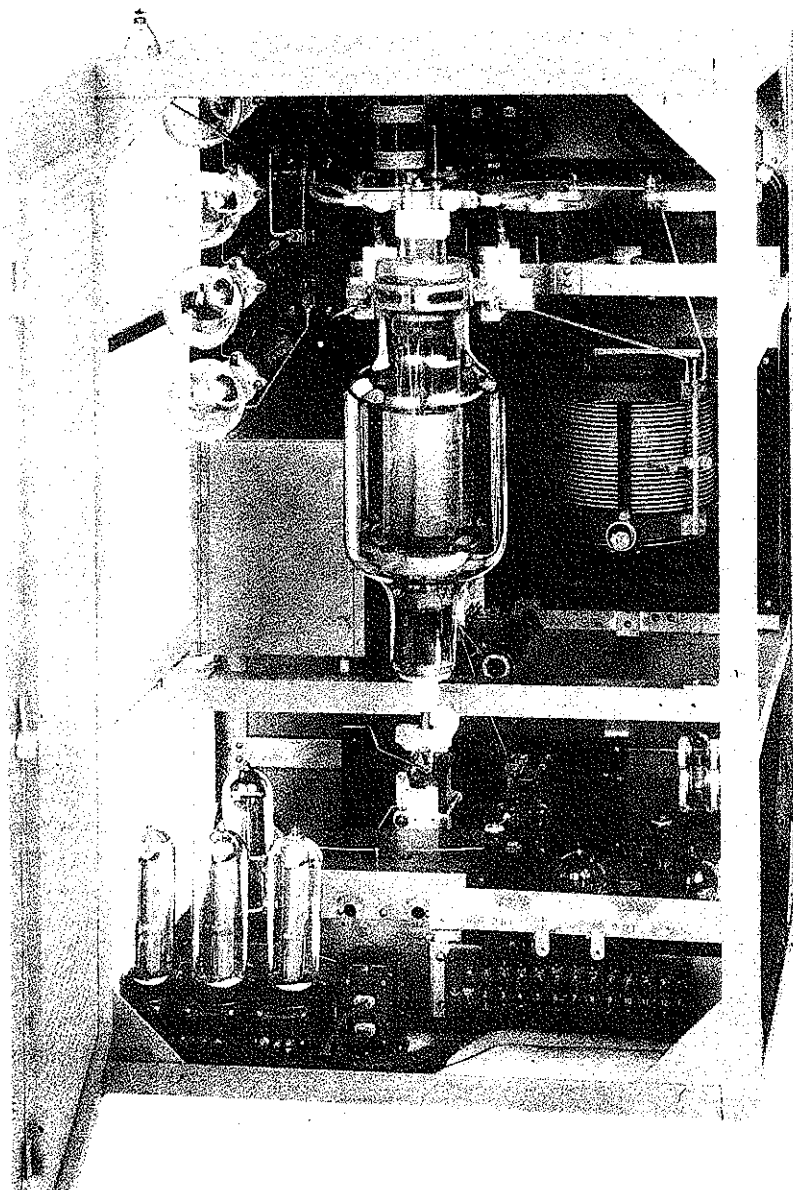


Figure 12

circuit of this tube and then impressed on the grid of a 50 watt modulating amplifier tube. The circuit arrangement of the audio-frequency amplifier portion of the transmitter requires three 50 watt tubes connected in parallel. The audio output of these tubes feeds through a transformer, marked MT in the diagram, and causes the amplitudes of the high-frequency oscillations present in

that circuit to undergo a variation in amplitude similar to the voice waves impressed on the microphone connected to the speech input circuit. The large tube in the center of the photograph is the radio-frequency power amplifier which operates with a plate potential of 2500 volts. The modulated carrier frequency is transferred from the output of this tube to the antenna through a feed line and condenser; this type of coupling effectively suppresses harmonics.

The output of the rectifier supplies a high potential of 2500 volts d-c for the power amplifier plate, and a low potential of 1000 volts d-c for plate supply to other tubes, and grid bias potentials of -55 and -200 volts. On the front panel are three meters for measuring these potentials. Also, 10 volts a-c is supplied for filaments. The power rating of this transmitter is 400 watts.

For reception at the ground station a short-wave receiver identical with the one in the airplane is used, and employs a similar volume control, but the tuning dial is mounted on the front of the panel. A desk stand microphone very similar to the standard telephone instrument is used for picking up the voice of the station's operator. To summarize this lesson it can be said that any system which permits two-way communication is obviously a distinct advantage because the pilot of a plane and the personnel in ground stations can remain in contact via radio.

EXAMINATION - LESSON 59-A

1. Name and give a brief explanation of each tube circuit in the Western Electric short-wave aircraft transmitter described in this lesson.
2. What are the advantages and disadvantages of two types of antennas used for aircraft?
3. You know that power can be generated for an aircraft radio transmitter and receiver by different methods. What are they and explain the advantages or disadvantages in each?
4. (a) How is the aircraft receiver tuned and, (b) how is volume regulated?
5. Why is a storage battery used in this equipment and how is it charged?
6. For this equipment what is the difference between the output rating of the dynamotor used for plate supply of the transmitter tubes, and the dynamotor used for plate supply of the receiving tubes?
7. Explain how plate voltage and filament voltage are obtained for the tubes in the ground transmitter.
8. If you were flying along an airway and desired to place the radio in readiness for two-way communication what would you do?
9. (a) What makes it possible to alternately "talk" and "listen" in the operation of an aircraft radio set?
(b) How is the transmitted wave maintained at the assigned frequency?
10. From this lesson name and describe the radio equipment installed in the cabin of a plane carrying a pilot and co-pilot for two-way communication.